



MECHANICAL CHARACTERIZATION OF RED MUD REINFORCED AL-8011 MATRIX COMPOSITE

K. V. Sreenivasrao¹, Anil. K. C.², Girish K. G.³ and Akash³

¹Department Mechanical Engineering, Siddaganga Institute of Technology, Tumakuru, India

²Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumakuru, India

³Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumakuru

E-Mail: kvsreenivasarao@yahoo.com

ABSTRACT

In the present investigation Red Mud Particle (Rmp) of average 90µm size was used as reinforcement and aluminum 8011 alloy was used as matrix material. Conventional stir casting method was employed to reinforce the Rmp with the matrix. Metallographic studies carried out using optical microscope, reveal fair distribution of reinforcement in the matrix material. Hardness of the matrix was found to increase by 52% with the addition of Rmp with loss of ductility. Ultimate tensile strength of the composites was found to be the high with the addition of 14 wt. % of Rmp (117.28 MPa) which follows gradual decrease with further addition of reinforcement. Compression strength was found to have maximum value of (76.001 KN) at 20% of Rmp. From the study, it is suggested to use 14 wt.% of red mud particles to obtain better performance level of MMC.

Keywords: red mud particle, stir casting, Aluminum 8011 alloy.

INTRODUCTION

Over the last 3 decades, composite materials, plastics and ceramics have been the dominant emerging materials. Metal matrix composites offer a number of advantages compared to their base metals, such as higher strengths and moduli, higher elevated temperature resistance, lower coefficient of thermal expansion, and in some cases better wear resistance. Metal matrix composites find their wide applications in automobiles, marine, aerospace industries [2]. Generally ceramics are widely used as reinforcement due to their desirable properties, such as high moduli, high compression strengths, high temperature capability, high hardness, wear resistance, low thermal conductivity and chemical inertness [4]. However, due to their very low fracture toughness, ceramics alone are limited in applications. Al_2O_3 , B_4C , SiC , TiO_2 , etc., are some of the widely used reinforcements. The selection of reinforcements depends on the cost, availability and other parameters. Performance level of MMC's depends on the Matrix material, type of reinforcement, processing methods, etc. [3].

Red Mud (RM) is the industrial waste or insoluble residue generated by the Bayer process which is used to extract aluminum from bauxite. Typical red mud may contain as much as 30-60% Fe_2O_3 , 10-20% Al_2O_3 , 3-50% SiC , 2-10% Na_2O , 2-8% CaO and 24% TiO_2 [11], depending upon chemical and mineralogical make up of bauxite and bauxite treatment technology [5-8]. Typical chemical composition of Indian red mud is tabulated in table-1. About 0.5-2 tonne of red mud is generated for each tonne of aluminum produced. The Indian bauxite

processing industries contribute over 1.9 million tonnes of red mud in about 40 million tonnes/year of red mud produced globally [9].

The abundance of red mud worldwide leads into waste unsuitable for treatment as well as disposal. As per the guidance of the Ministry of Environment and Forest and climate change, Government of India, the production units are investing crores of rupees in India to treat and dispose the residue without any environmental effect and researchers have been involved to find the safe disposal, neutralization or recultivation of old dumps[10]. In the present research work, Red-mud particle (Rmp) is selected as reinforcement as a low cost option. Red mud alone consists of many ceramic contents like Al_2O_3 , B_4C , SiC , TiO_2 and is abundantly available.

EXPERIMENTAL PROCEDURE

A. Materials

The attractiveness of aluminum is that it is a relatively low cost, light weight metal with fairly high strength and easy to fabricate. Aluminum of series 8011 was selected as a matrix. Red mud particles are selected as a reinforcing material. Al-8011 was procured from the Plas-met-chem Corporation, Bengaluru. The chemical composition of Al-8011 is listed in Table-2. Rmp was procured from the HINDALCO aluminum refinery, Belagavi, India. Raw red mud granules are then ball milled in order to achieve fine powdered structure. Milled powder is then sieved to segregate the different sizes. The average



size of 90 μ m was selected for the reinforcement. The presence of different elements is confirmed by gravimetric test and the results are tabulated in the table 3. Weighed quantity of Al-8011 was melted in electrical resistance

furnace to desired superheat temperature of 750°C in graphite crucible. After attaining the required temperature, degassing agent (C₂Cl₆ - solid hexachloro ethane) was added in order to degas the entrapped gases in the melt.

Table-1. Chemical composition of Indian red muds [11].

Company	Al ₂ O ₃ %	Fe ₂ O ₃ %	SiO ₂ %	TiO ₂ %	Na ₂ O%	CaO %	LOI%
BALCO, Korba	18-21	35-37	6-7	17-19	5-6	2-3	11-14
HINDALCO, Renukoot	17-19	35-36	7-9	14-16	5-6	3-5	10-12
HINDALCO, Muri	19-21	44-46	5-7	17-19	3-4	1-2	12-14
HINDALCO, Belgaum	17-20	44-47	7-9	8-11	3-5	1-3	10-14
MALCO, Metturdam	18-22	40-46	12-16	3-4	4-5	1-3	11-15
NALCO, Damonjodi	17-20	48-54	4-6	3-4	3-5	1-2	10-14

Table-2. Chemical composition of Aluminum 8011.

Element	Al	Fe	Si	Mn	Zn	Cu	Ti	Cr	Mg
Content (%)	97.3 - 98.9	0.60 - 1	0.50 - 0.90	≤ 0.20	≤ 0.10	≤ 0.10	≤ 0.08	≤ 0.050	≤ 0.050

Table-3. Chemical composition of red mud.

Element	Al ₂ O ₃ %	Fe ₂ O ₃ %	SiO ₂ %	TiO ₂ %	Na ₂ O%	CaO%	LOI%
Content (%)	18.34	45.93	7.23	9.56	3.42	1.0015	8.00145

Then the molten metal was stirred manually at an average speed of 300 rpm for 200 Sec to form a vortex in the melt. Once the vortex is achieved the preheated (300±20°C) RMP was added by varying weight percentage of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 respectively. Prepared molten metal then poured in preheated cast iron mould and allowed to solidify.

B. Characterization

The composite specimens were machined to prepare tensile and compression specimens as per the ASTM E8M and ASTM E09 respectively. Then the prepared specimens were tested at room temperature by using universal testing machine. Metallographic studies help to identify the precipitates, phases, and constituents and also the study helps the determination of shape and size of the grains, characteristics of grain boundaries and

other defects such as cold shut, pores and agglomeration [12]. Specimens are polished as per the metallographic procedure and etched (Keller's reagent -2.5% HNO₃+1.5% HCl+1% HF+95% H₂O) prior to the characterization. ASTM-E10-93 was followed to determine the hardness with a ball diameter of 10mm with a fixed load of 500kg at different locations of the specimens using Brinell Hardness Tester.

RESULT AND DISCUSSIONS

The distribution of RMP in aluminium matrix was examined by optical microscope Figure-1 shows the optical images of matrix material and the composite with various weight percentages of RMP. Optical images gives visual confirmation of even distribution of fine RMP and also agglomeration of particles in certain locations of the matrix.

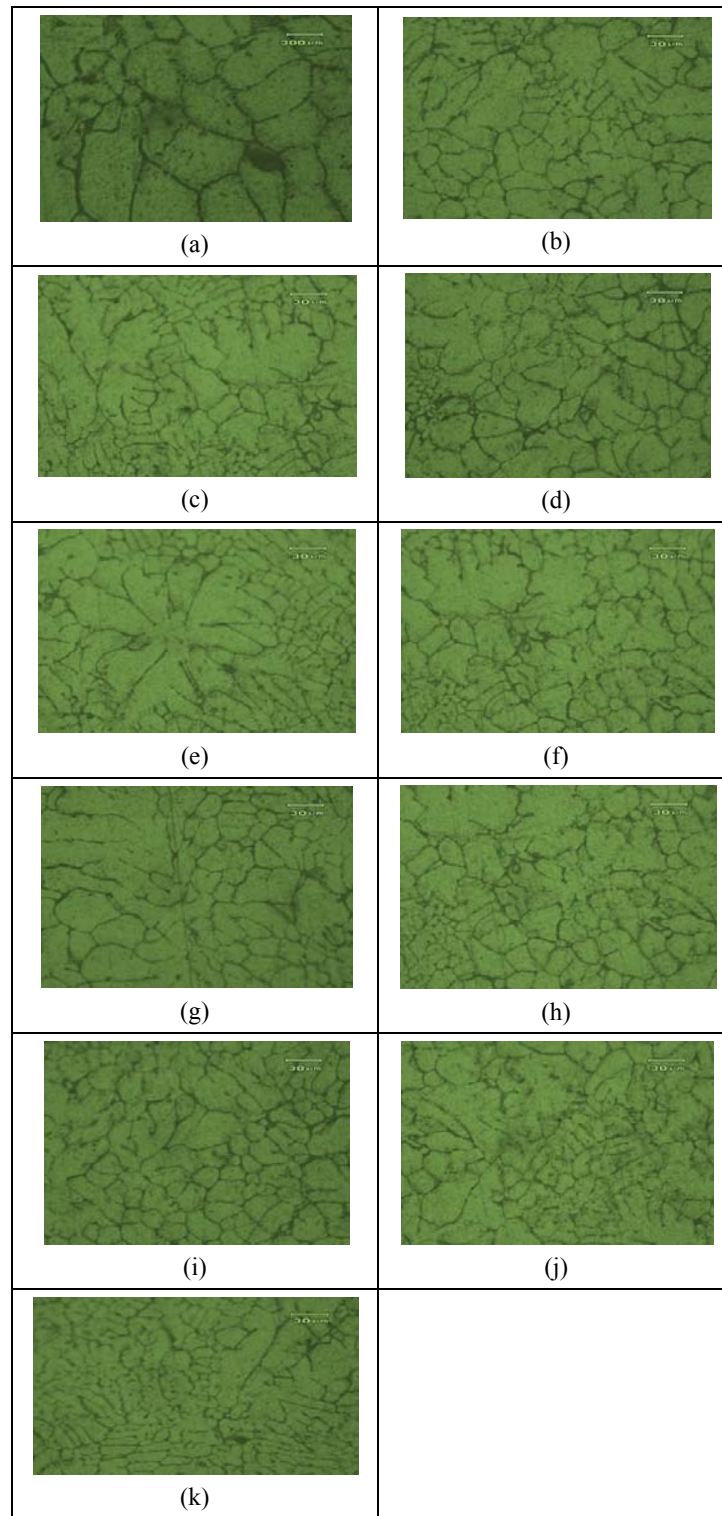


Figure-1. Optical images of (a) As cast (b) 2Wt % RMp (c) 4Wt % RMp, (d) 6Wt % RMp, (e) 8Wt % RMp (f) 10Wt % RMp, (g) 12Wt % RMp, (h) 14Wt % RMp, (i) 16Wt % RMp (j) 18Wt % RMp, (k) 20Wt % RMp.

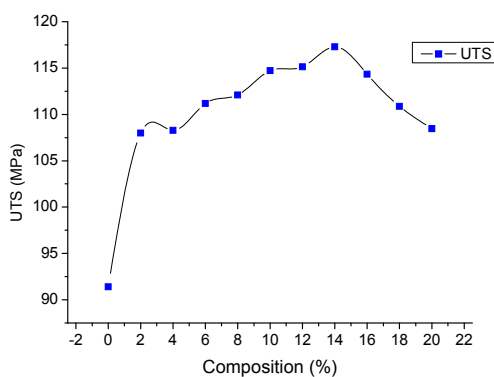


The hardness of the matrix and composite were evaluated at 5 different locations of the prepared specimens using Brinell hardness tester and average of 5 readings are tabulated in table 4. From the micro structures it is clear that the grain size is reducing with increasing in weight percentage of reinforcement. From the results obtained it was observed that with the increases in weight percentage of RMp the hardness value of the composite

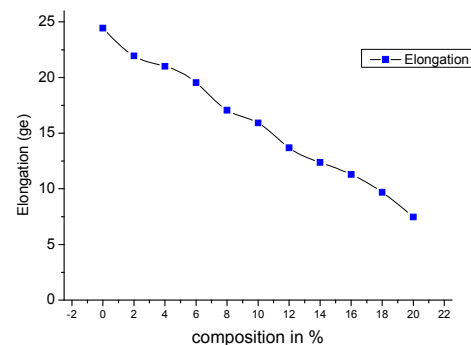
increases by 52%. Tensile strength of the composites are shown in Figure-2(a). From the figure we can say the capacity of withstanding applied tensile load is increased with 18% with addition 2 weight percentage of reinforcement. Further increase in weight percentage of RMp will enhance the load bearing capacity from 107.995 MPa to 117.28 MPa.

Table-4. Mechanical properties of composite with different weight percentage of RMp.

Sl. No.	Compositions	Tensile UTS (MPa)	% of elongation	Compression Strength (KN)	Hardness (BHN)
	Base Metal (Al-8011)	91.405	24.44	38.06	21.3
	Al+ 2% RMp	107.995	21.94	40.29	22.5
	Al+ 4% RMp	108.28	21.01	44.66	27.0
	Al+ 6% RMp	111.175	19.54	50.16	27.19
	Al+ 8% RMp	112.09	17.06	58.73	28.5
	Al+ 10% RMp	114.725	15.92	65.92	29.92
	Al+ 12% RMp	115.125	13.68	73.66	31.1
	Al+ 14% RMp	117.28	12.37	74.92	31.92
	Al+ 16% RMp	114.349	11.293	75.02	32.56
	Al+ 18% RMp	110.87	09.69	75.92	33.859
	Al+ 20% RMp	108.46	07.46	76.001	34.98



(a)



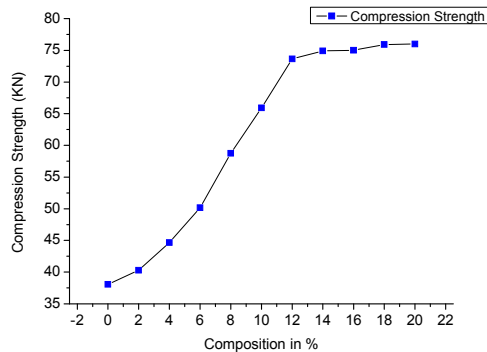
(b)

Figure-2. (a)Tensile properties of composite with different weight percentage of RMp (b)Percentage elongation of composites with different weight percentage of RMp.

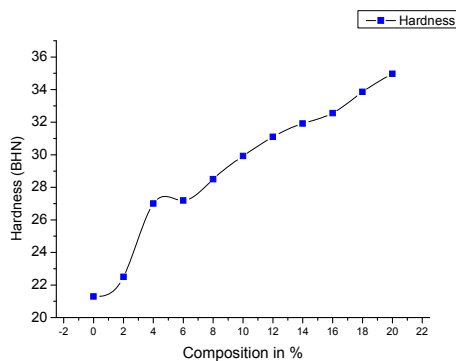
When material become harder it loses its ductility and limited plastic deformation was observed in the matrix materials this was evident in Figure- 2(b) with the increase



in wt% of the reinforcement the percentage of elongation is also decreasing.



(a)



(b)

Figure-3. (a) Compression strength of composite with different weight percentage of RMp (b) Hardness of composites with different weight percentage of RMp.

Compression strength of various compositions are shown in Figure-3 (a), the compression strength of a base alloy Al-8011 is 38.06 KN. The load bearing capacity of matrix material will increased with the addition of reinforcement.

CONCLUSIONS

With the conventional stir casting route it is possible to develop an Al-RMp composite with uniform distribution of reinforcement. Addition of RMp in matrix metal will lead to higher hardness value. Tensile strength of composite increases by 27% with the addition of 14 weight percentage of RMp. Compression strength of metal matrix composites increased to 76.001 KN from 38.06 KN. From the overall results it is observed that 14 wt% of RMp is a fair value to obtain better performance of

composite. These results help to upcoming researchers to use the Red mud, an industrial residue, as reinforcement for better waste management and property enhancement of the matrix material.

REFERENCES

- [1] Saravana Bhavan K, Suresh S, Vettivel S C. 2013. "Synthesis, Characterization and Mechanical Behavior of Nickel Coated Graphite on Aluminum Matrix Composite" International Journal of Research in Engineering and Technology. 2(11): 749-755.
- [2] N. Senthilkumar, T. Tamizharasan, M. Anbarasan. 2014. "Mechanical Characterization and Tribological Behaviour of Al-Gr-B4c Metal Matrix Composite prepared by Stir Casting Technique", Journal of Advanced Engineering Research ISSN: 2393-8447. 1(1):48-59.
- [3] F. Akhlaghi, A. Lajevardi, and H.M. Maghanaki. 2004. "Effects of casting temperature on the microstructure and wear resistance of compo cast A356/SiCp composites: a comparison between SS and SL routes", Journal of Materials Processing Technology, 155-156, 1874-1880.
- [4] F.C. Campbell. 2006. "manufacturing technology for aerospace structural materials", Butterworth-Heinemann publications, ISBN: 978-1-85-617495-4, Elsevier Inc.
- [5] A.S. Wagh and P. Desai (Eds.) 'Bauxite Tailings "Red Mud" The Jamaican Bauxite Institute and the University of West Indies, Kingston 1987.
- [6] L. Piga, F. Pochetti and L. Stoppa. 1993. ' J. Metals', 11, p. 54.
- [7] P.M. Prasad, J.S. Kachawha, R.C. Gupta, T.R. Mankhand and J.M. Sharma. 1985. ' Light Metals Science and Technology', Trans. Tech. Publications Ltd., Switzerland, p. 31.
- [8] R.S. Thakur and S.N. Das, 'Red Mud Analysis and Utilisation and Recovery of Metal Values', Publications and Information Directorate (C SIR) and Wiley Eastern Limited, New Delhi, India.
- [9] Rakesh Kumar, J.P. Srivastava and Premchand. 1998. "Utilization of iron values of red mud for



metallurgical applications Environmental and Waste Management" (ISSN: 0971-9407), pp. 108-119.

- [10] Vladimar cablik, "Characterization and applications of red mud from bauxite processing" VSB- Technical University of Ostrava, faculty of mining and geology, Czech Republic, pp. 27-38.
- [11] Harekrushna Sutar, Subash Chandra Mishra, Santosh Kumar Sahoo, Ananta Prasad chakraverty and Himanshu Sekhar Maharana. 2014. " Progress of Red Mud Utilization: An Overview" American Chemical Science Journal. 4(3), pp. 255-279.
- [12] M.F. Ibrahim, H.R. Ammar, A.M. Samuel, M.S. Soliman, and F.H. Samuel. 2013. "Metallurgical parameters controlling matrix/B₄C particulate interaction in aluminium–boron carbide metal matrix composites", International Journal of Cast Metals Research, 26(6), pp. 364-373.